
Detection of hyperacusis condition in tinnitus patients based on PLSC features that link audiogram and fMRI tonotopy responses

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Tinnitus is the chronic perception of ringing or other phantom sounds. Some tinnitus patients additionally suffer from loudness hyperacusis that is the over-sensitivity to environmental sounds. Here, we recruited eight patients with unilateral hearing loss and tinnitus, among which four also have loudness hyperacusis. For every patient, the audiogram was acquired by measuring the audible thresholds for 9 frequency presentations in the range 125Hz-8kHz with steps of half an octave. The fMRI data was recorded on a 7T MRI scanner that allows exquisite spatial resolution of 1mm^3 . The experimental paradigm was according to the tonotopic mapping experiment by (Da Costa et al., 2011), which consists in presenting a sequence of 15 pure frequency tones in 14 cycles (88Hz-11340Hz). Voxels from the auditory cortex are then extracted and their timecourse is fitted to the sine/cosine with the period of the block-based paradigm, which gives access to the amplitude and the phase of the response. Voxels are labeled using the relationship between the phase and the presented frequency, and then amplitudes of voxels with same label are averaged resulting into 15 fMRI features/subject. We then use partial least-squares correlation (PLSC; Krishnan et al., 2011) to establish the link between the audiogram measures and the fMRI tonotopy responses. By maximizing correlation in a multivariate way, PLSC identifies a set of latent variables (LVs) that each contain an fMRI saliency vector and two audiogram saliency vectors (one for each group; i.e., hyperacusis and non-hyperacusis). Using permutation testing, we found evidence for a single LV being significant ($p < 0.05$). We then deploy this feature extraction within a cross-validation scheme (leave-one-subject-out) and combine it with an SVM classifier. Every subject has three features obtained after reprojecting the non-normalized data on the PLSC model; i.e., one fMRI-derived brain score and two audiogram-derived behavior scores for the significant LV. We found 75% accuracy and a precision score of 4.5 (i.e., average distance from the decision plane). Direct classification of the audiogram and fMRI features led to 82% accuracy with reduced precision score of 0.9. This is the first study that clearly establishes a link between behavioral (audiogram measures) and brain signals (fMRI tonotopy responses). We show that this relationship captures in one LV the essential information that is needed for detecting hyperacusis patients. In Fig. 1a, we show the audiogram saliencies

for both groups (with bootstrapped confidence intervals). The hyperacusis patients show a contrast between low ($<4\text{kHz}$) and high ($>4\text{kHz}$) frequencies. However, for non-hyperacusis patients, the audiogram-based saliency only seems to increase for higher frequencies. This is in analogues to the brain saliencies shown in Fig. 1b. The tonotopic map is shown in Fig. 1c as a reference for the brain saliency map in Fig. 1d for a sample subject. We can infer that the increase of brain signal in specific parts of the brain is related to the imbalance in frequency sensitivity as measured by the audiogram. Our results do not only show that it is possible to detect hyperacusis patients, but it might also open new avenues to study the neural mechanisms that underlie this condition.

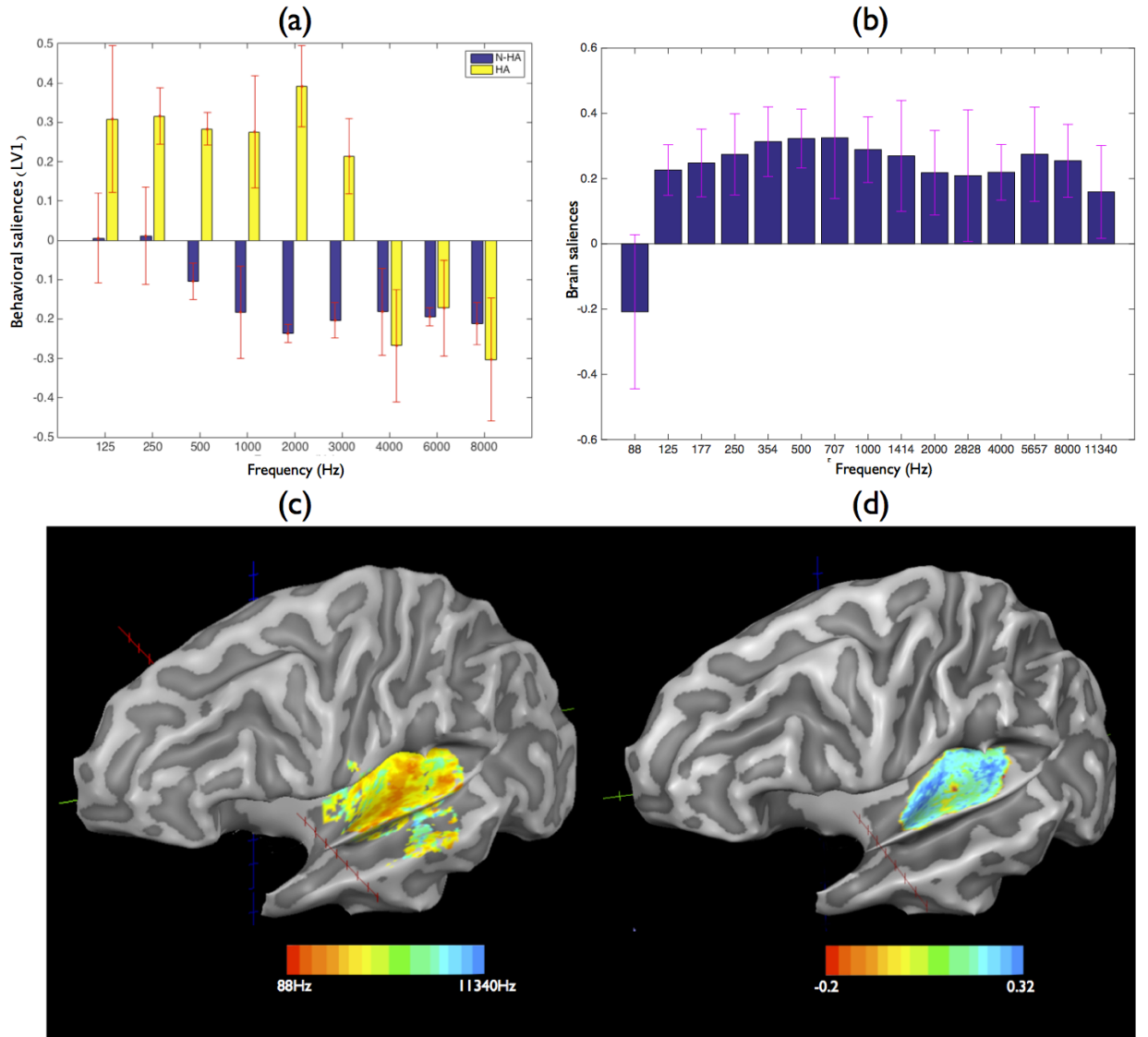


Figure 1: Results for the significant PLSC latent variable. (a) Behavioral saliencies for hyperacusis (HA) and non-hyperacusis (N-HA) groups. (b) Brain saliencies for tonotopy experiment frequencies. (c) Tonotopic map in auditory cortex of a sample subject. (d) Brain saliencies projected on the cortical surface of a sample subject (auditory cortex).

References

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